Large-Scale Outflows in Edge-on Seyfert Galaxies.
I. Optical Emission-line Imaging and Optical Spectroscopy

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ABSTRACT

We have launched a search for large-scale ($\gtrsim$1 kpc) minor-axis outflows in edge-on Seyfert galaxies in order to assess their frequency of occurrence and study their properties. Here we present optical continuum and Hα+[NII] line images and/or minor-axis long-slit spectra of 22 edge-on Seyfert galaxies. Six of these galaxies show at least one of the following: (i) bi-symmetric Hα halos extending along the minor axis, (ii) bright emission-line complexes at distances $\gtrsim$4 kpc (in projection) out of the disk, and (iii) double-peaked emission-line profiles from the gas along the minor-axis, suggesting that a wind-blown bubble is present. Our results indicate that $\gtrsim\frac{1}{4}$ of Seyferts have good evidence for minor-axis galactic outflows.

Kinetic luminosities of the galactic outflows in our sample Seyferts are $\sim 10^{40} - 10^{42}$ erg s^{-1}, assuming all of the observed minor-axis emission is produced by the outflow. These values are, in general, $\sim$0.1 as large as those for well-studied cases of superwinds in starburst galaxies (Heckman, Armus & Miley 1990). However, far-infrared luminosities of our sample Seyferts are also $\sim$0.1 as large. Both starburst-driven superwinds and wide-angled outflows from the active galactic nucleus are possible explanations for the observed large-scale outflows.

Subject headings: galaxies: Seyfert — ISM: jets and outflows

1. Introduction

Ionized gas is known to extend (up to ≈1 kpc) out of the plane in normal spiral galaxies (e.g. Dettmar 1992). The origin and maintenance of this component of the interstellar medium in normal galaxies is not completely understood, but most theories support the notion that it is energized by outflows from the galaxy disk (cf. Rand 1995).

In powerful infrared (IR) galaxies, extraplanar ionized gas is much more luminous and is detectable much further (up to tens of kpc, Heckman, Armus & Miley 1990) out into the halo. The origin of these more extended structures is also explained by outflows from the galaxy. Nuclear starbursts in these galaxies produce stellar winds and supernovae which rapidly heat the gas in the nuclear region. This high-pressure gas then expands rapidly and blows a wind out of the nuclear region, along the rotation axis of the disk, where the pressure gradient is lowest. This 'superwind' interacts with clouds of dense gas in the galaxy and its halo, producing optical emission-line filaments (see, e.g., Heckman, Armus & Miley 1990). Material swept up by the wind accumulates behind the shock front, forming a large shell (or 'bubble') along the minor axis. Line emission which is observed from the shell should then have two velocity components, one from the front surface of the shell and one from the rear surface. Such double-peaked emission-line profiles are indeed commonly found in minor axis spectra of superwind galaxies (cf. Heckman, Lehnert & Armus 1993), corroborating that wind-blown bubbles are present.

Superwinds also manifest themselves at radio and X-ray wavelengths. The radio halos in edge-on starburst galaxies produce synchrotron emission from relativistic electrons in the wind. Thermal X-rays are emitted by hot, expanding gas in the bubble and by low-density halo clouds which have been shocked by the wind. A well studied example of an extended halo is that in the edge-on starburst galaxy M82 (radio: e.g., Seaquist & Odegard 1991; X-ray: Bregman 1994). More examples are discussed in a recent review of observational

and theoretical aspects of superwinds in starburst galaxies by Heckman, Lehnert & Armus (1993).

Approximately 1% of spiral galaxies have an active (Seyfert) nucleus, which is commonly believed to be an accretion-powered supermassive black hole, i.e., a scaled-down version of a quasar (see, e.g., Terlevich 1992 for an alternate view). The emission from the active galactic nucleus (AGN) dominates the luminosity at most wavelengths, so most studies of Seyferts have focused on observing the properties of the AGN itself and the environment it creates in and immediately around the nuclear region (see, e.g., Antonucci 1993). There is good evidence that nuclear outflows exist on pc scales in some Seyferts (cf. Wilson 1993), but it is not clear that these small-scale ($\lesssim$1 kpc) outflows are connected with large-scale galactic outflows.

Observations of the large-scale ($\gtrsim$1 kpc) emission in Seyferts do show that, in some cases, galactic-scale minor-axis outflows are present (e.g., Hummel, van Gorkom & Kotanyi 1983, Hamilton & Keel 1987, Corbin et al. 1988, Wehrle & Morris 1988). In a sample of Seyfert galaxies selected for extended optical or radio emission, Baum et al. (1993) found kpc-scale radio emission extending preferentially along the minor axes in seven out of ten cases and suggested that the emission comes from galactic winds blowing out of the galaxy disks. A particularly good example of a galactic outflow can be found in the edge-on Seyfert galaxy NGC 5506. Diffuse radio emission is found out to ∼300 pc from the nucleus in the direction of the minor axis (Wehrle & Morris 1987) and double-peaked emission-line profiles are found in minor axis spectra from regions ∼500 pc above and below the disk (Wilson, Baldwin & Ulvestad 1985). The question of what powers galactic outflows in Seyferts remains open, but viable sources of kinetic energy are nuclear starbursts and the active nucleus.

Why study galactic outflows in Seyferts? So far, only anecdotal evidence has been

presented for them and they have not been systematically studied. One would like to know how galactic outflows in Seyferts are different from those in more powerful AGNs (e.g. radio galaxies, BALQSOs) and also from those in starburst galaxies. From a broader standpoint, one would like to know what influence the outflows have on the AGN and its host galaxy. Galactic outflows drive large amounts of gas (and metals) out of the nuclear region, whereas the AGN needs a constant supply of gas flowing inward. Thus, galactic outflows in Seyferts may regulate the power output and lifetime of the active nucleus. If the outflows are driven by starbursts, then what role, if any, do these nuclear starbursts play in the formation and evolution of the active nucleus? Many workers have proposed scenarios in which Seyferts and starbursts are connected in an evolutionary sense (e.g. Scoville 1992), but the issue remains open. The outflows may also have a strong influence on the physical state of the intergalactic medium. Plasma which is blown out of the galaxy will increase the density of the intergalactic medium, heat it, and enhance its metallicity.

In order to address these questions, we have begun a research program to systematically study a complete sample of edge-on Seyfert galaxies. We shall search for observational evidence of galactic outflows, determine their physical properties and investigate possible energy sources for driving the outflows. In paper I, we present optical emission-line images and/or minor-axis spectra of the ionized gas in 22 edge-on Seyfert galaxies. Our future work will consist of analyzing the large-scale radio and X-ray emission from these outflows, using the same sample of edge-on Seyferts.

In section 2, we introduce a statistical sample of Seyfert galaxies which we shall use for continuing studies. Observations and data reduction techniques are described in section 3 and images and spectra are presented for individual objects in section 4. In section 5, we discuss the frequency of occurrence of large-scale outflows in Seyferts and discuss possible interpretations of energy sources driving the outflows. A Hubble constant of 75

km s^{-1} Mpc^{-1} is assumed throughout this paper.

2. Definitions of Samples

Extended optical emission-line gas is difficult to observe in face-on disk galaxies, due to confusion with emission from the disk. We have therefore chosen to study only edge-on systems.

We have defined a 'complete,' distance-limited statistical sample of edge-on Seyferts which we shall use in continuing studies. First, we selected Seyferts (LINERs were omitted) from an electronic version of the Seyfert catalog by Huchra (1993). This list was cross-referenced by position with an electronic version (vers. 3.9) of the *Third Reference Catalog of Bright Galaxies* (de Vaucouleurs et al. 1991;RC3). Using recessional velocities (cz; 21 cm preferred) and axial ratios (R_{25}; major to minor) from RC3, we then selected objects by restricting $cz \leq 5500$ km s^{-1} and $\log R_{25} \geq 0.4$ ($R_{25} \geq 2.5$). Using the same method, we made another list starting from an electronic version of Veron-Cetty & Veron's (1991) Seyfert catalog. The two lists were then combined. A few additional Seyferts which satisfied the restrictions listed above were selected by hand from Hewitt & Burbidge (1991) and from the literature. Our complete sample consists of 22 objects. Morphological types, positions, axial ratios, recessional velocities and Seyfert types for each galaxy are listed in Table 1.

We have obtained Hα+[NII] images and/or long-slit spectra (near Hα) for 14 of these 22 objects. No bias was used to select these objects for observation. Henceforth, we will refer to this sub-sample (marked by a dagger [†] in Table 1) as our 'representative' sample and shall use it for computing statistics in section 5.

We have also obtained images and/or spectra for eight additional edge-on Seyferts

which have $cz > 5500$ km s^{-1}, $\log R_{25} < 0.4$, or both. Morphological types, positions, axial ratios, recessional velocities and Seyfert types for these galaxies are listed in Table 2.

Hereafter we shall refer to the sample of all objects observed as our 'extended' sample. These 22 objects are the 14 objects marked by a dagger in Table 1 plus the eight objects listed in Table 2. We shall use this extended sample for computing statistics as well (section 5).

3. Observations and Data Reduction

A log of new imaging and spectroscopic observations using the KPNO[1] 2.1 m telescope is given in Table 3. These data were supplemented by additional Hα+[NII] images, taken at the 2.1 m telescope at KPNO, the 1.5 m telescope at the Cerro Telolo Inter-American Observatory (CTIO), and the 2.2 m telescope at the European Southern Observatory (ESO). Information about the observations for these supplemental images can be found in Mulchaey, Wilson & Tsvetanov (1996) and Tsvetanov, Fosbury & Tadhunter (1995).

Reduction of the data was performed using the CCDPROC analysis programs in IRAF[2] . The raw CCD images were processed in the normal fashion by subtracting bias frames and dividing by normalized images of the dome or blank sky. Atmospheric extinction corrections were performed (for all of the data) using extinction curves appropriate for each observing site.

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[1] Kitt Peak National Observatory of the National Optical Astronomy Observatories (NOAO), operated by AURA, Inc., under contract with the National Science Foundation.

[2] IRAF is the imaging analysis software developed by NOAO.

During the imaging runs at the KPNO 2.1 m (August 1992 and February 1993), two exposures of 1800 s were taken through narrow-band (full width at half maximum [FWHM] $\sim$ 75Å) filters centered near Hα. To produce an image of only the Hα+[NII] line emission, an R-band image (exposure 300 s) was scaled and subtracted from the narrow-band image. Observations of spectrophotometric standard stars were used to flux calibrate the Hα+[NII] images. The limiting surface brightness levels of the Hα+[NII] images are $\sim$1 $\times$ 10^{-16} erg s^{-1} cm^{-2} $arcsec^{-2}$.

The long-slit spectra were taken in January and June 1992 at the KPNO 2.1 m telescope. Two exposures of 1800 s were taken with the slit oriented parallel to the galaxy's minor axis and passing through its nucleus. One exposure of 1800 s was taken along the major axis. Frequent observations of a quartz lamp were used to remove the high spatial frequency structure. HeNeAr spectra were used for wavelength calibration and observations of spectrophotometric standard stars were used for absolute flux calibration. The width of the slit was 1.75″, except for Ark 79, NGC 931, NGC 5506 and IC 1368, for which it was 2.0″. Limiting surface brightness levels at Hα are a factor of several better that those for the imaging data. The spectral coverage included Hα, [N II] $\lambda\lambda$ 6548, 6583 and [S II] $\lambda\lambda$ 6716, 6731.

Continuum-free Hα+[NII] images from Mulchaey, Wilson & Tsvetanov (1996) and Tsvetanov, Fosbury & Tadhunter (1995) were made by combining narrow-band (FWHM $\sim$50$-$100Å) images centered on Hα with narrow-band images of the nearby continuum. The images were flux calibrated from observations of spectrophotometric standard stars. Exposure times were typically $\sim$1000$-$2000 s and the limiting surface brightness levels were $\sim$2 $\times$ 10^{-16} erg s^{-1} cm^{-2} $arcsec^{-2}$ (except for the Hα+[NII] image of NGC 5506, for which the exposure time was much shorter and the limiting surface brightness is a factor of $\sim$10 higher).

4. Results

Descriptions of the observational data are given in Table 4. For each of the 22 objects observed, we list the type of data taken and the corresponding figure number for the images and/or spectra. We also list the total Hα+[NII] luminosity from the galaxy for all objects for which we have Hα+[NII] images, and the total Hα+[NII] luminosity from the minor-axis emission-line gas for galaxies in which emission-line regions (ELRs) are evident along the minor axis. The total Hα+[NII] luminosity from the galaxy was calculated by summing the flux inside rectangular regions enclosing all of the emission-line nebulae from the galaxy. The Hα+[NII] luminosities of the minor-axis ELRs were calculated by summing flux inside rectangular regions around the individual ELRs mentioned in sections 4.1 and 4.2.

In the following subsections, we present and discuss our new images and spectra and also note whether other data which has been published is suitable for searching for evidence for minor-axis outflows. Seyferts which are good candidates for having such outflows are identified and statistical results for our samples are discussed in section 5.

4.1. Individual Objects: Complete Sample

For each of the galaxies in our complete sample, we searched the literature for published data which could be used to look for signatures of minor-axis outflows. For many of the objects (IC 1657, UM 319, Mrk 993, Mrk 577, Ark 79, NGC 1320, MCG −2-27-9, NGC 4602, ESO 103-G35, NGC 6810, IC 1417, NGC 7410 and NGC 7590), the published data was not suitable. Exceptions are noted in the following subsections.

4.1.1. Mrk 993

Our images for Mrk 993 are shown in Figure 1a. Many ELRs are scattered throughout the galactic disk, but no minor-axis emission is evident in our Hα+[NII] image. We did not find double-peaked line profiles or any evidence for ELRs extending out of the disk in our minor axis spectra.

4.1.2. Ark 79

No extraplanar emission is noticeable in our Hα+[NII] image (Figure 1b). The spectrum from the position 3.1$''$ ($\sim$1 kpc) south (along the minor axis) of the nucleus may have double-peaked Hα, [NII] and [S II] emission line profiles (consistent with what is expected from the shell of an wind-blown bubble), but the possible substructure in the profiles is nearly the same level of magnitude as the noise. For this reason, we have classified these features as only suggestive of a minor axis outflow. Spectra with higher signal-to-noise (S/N) ratios would be useful for determining if these components are double peaked emission lines from a wind-blown bubble.

4.1.3. NGC 931 (Mrk 1040)

Our R-band image (Figure 1c) shows the presence of a companion galaxy $\sim$20$''$ to the north along the minor axis. Apart from emission from this companion galaxy, we find no extended Hα+[NII] emission in our long-slit spectra along the minor axis. Fabry-Perot studies (e.g. Amram et al. 1992) show that the kinematics of the emission-line gas are quite complex, but there is no evidence for an outflow from the nucleus.

4.1.4. NGC 1320 (Mrk 607)

No minor axis emission is noticeable in our Hα+[NII] image (Figure 1d). This galaxy forms a pair with NGC 1321, which is positioned $\sim$1.7$'$ to the north.

4.1.5. NGC 1386

NGC 1386 is located in the Fornax cluster, so we have used the distance to that cluster (20 Mpc) in our calculations. In the Hα+[NII] image (Figure 1e), there is an ELR with luminosity 3.1×10^{38} erg s^{-1} to the northwest, at a distance of 41$''$ (4.0 kpc) from the nucleus. The continuum emission from the disk extends out to this position, so the ELR could lie in the the plane of the galaxy disk. Alternatively, the emission could be from gas in a halo cloud which has been ionized by a wind. Weaver, Wilson & Baldwin (1991) have used long-slit spectroscopy to study the kinematics of the extranuclear gas within $\sim$12$''$ ($\sim$1 kpc). The line profiles and line ratios of the ELRs surrounding the nucleus suggest that an outflow from the nucleus may be occurring along the *major* axis. Ulvestad & Wilson (1984) found that the morphology of the nuclear radio continuum emission is slightly extended $\sim$ 400 pc toward the southwest along position angle (P.A.) $-125°$. Although there is good evidence for a nuclear outflow in NGC 1386, it does not appear to be directed along the minor axis. Except for the northwest ELR, all of the line emission originates from $\lesssim$1 kpc. More solid evidence is needed to conclude that a galactic scale outflow (i.e. one blowing out of the galactic disk) is present in this galaxy.

4.1.6. NGC 2992

A dust lane separates the line emission which immediately surrounds the nucleus (see Figure 1f) from the bright ($L_{H\alpha+[NII]} = 3.6 \times 10^{40}$ erg s^{-1}) ELR which extends from $\sim$5$-$15$''$ (0.6$-$2.2 kpc) to the northwest, in the direction of the minor axis. A number of ionized filaments of luminosity $\sim 10^{38}$ erg s^{-1} are also present beyond the northwest ELR, at distances $\leq$30$''$ (4.5 kpc). Such bright filamentary structures are commonly found in luminous IR galaxies with starburst-driven superwinds (e.g. Heckman, Armus & Miley 1990). Tsvetanov, Dopita & Allen (1995) find evidence for outflowing gas with velocities $\sim$200 km s^{-1} on both sides of the galaxy disk. Radio continuum maps of the nuclear region of NGC 2992 show emission extending out to 2$''$ (0.3 kpc) along the minor axis which has the structure of "striking pair of loops" (Wehrle & Morris 1988). These authors interpret these loops as limb-brightened bubbles or magnetic arches. The bright minor-axis optical ELRs and 'Figure-8' radio morphology suggest that a powerful galactic outflow is occurring in NGC 2992.

4.1.7. MCG −2-27-9

Our Hα+[NII] image (Figure 1g) shows emission from the disk but no extended emission along the minor axis.

4.1.8. NGC 4235 (IC 3098)

No extended minor-axis emission is apparent in our Hα+[NII] image (Figure 1h) of NGC 4235. ELRs are noticeable extending from the nucleus out along the *major* axis, especially to the northeast (see also Pogge 1989). We did not find double-peaked line

profiles or any evidence for ELRs extending out of the disk in our minor axis spectra. Radio continuum maps of the nuclear region (Ulvestad & Wilson 1989) are unresolved or very slightly resolved. No extended emission was noticed by Hummel, Beck & Dettmar (1991) in their large-scale radio map.

4.1.9. NGC 4388

We did not obtain any new images or spectra of NGC 4388 since there is already good evidence for a galactic outflow in this galaxy. Corbin, Baldwin & Wilson (1988) and Pogge (1988) have shown that conical structures of ionized gas extend outward from the nucleus, both above and below the disk. These authors argue that some of the line-emitting gas may have been ejected from the nucleus. Radio maps of this galaxy (Hummel et al. 1983; Stone, Wilson & Ward 1988) reveal diffuse emission extending outward from the nucleus, perpendicular to the galactic disk.

4.1.10. NGC 4602

Much of the emission in our Hα+[NII] image (Figure 1i) comes from a ring structure in the disk (Buta & de Vaucouleurs 1983), but no emission is evident along the minor axis.

4.1.11. NGC 4945

This Seyfert galaxy also houses a strong nuclear starburst. The presence of a superwind in this this galaxy has been discussed in detail by Heckman, Armus & Miley (1990), who

argue that the wind is driven by the starburst. Harnett et al. (1989) present images of a radio halo in this galaxy, presumably produced by the wind.

4.1.12. IC 4329A

A bi-symmetric halo of emission-line gas can be seen in our Hα+[NII] image (Figure 1j) extending along the minor axis, $\sim$10$''$ (3 kpc) on both sides of the nucleus. The Hα+[NII] luminosity of the extended emission on either side is $\sim 2.5 \times 10^{39}$ erg s^{-1}. Unger et al. (1987) show that radio emission extends $\sim$6$''$ west from the nucleus and suggest that it is from material lying out of the plane. The Hα halo we observe here is probably produced by an outflow from the nuclear region and we consider IC 4329A a good candidate for a large-scale galactic outflow.

4.1.13. NGC 5506

Emission-line nebulae extend along the minor axis, $\sim$5$''$ (0.6 kpc) north and south of the nuclear region (see Figure 1k). Wilson, Baldwin & Ulvestad (1985) first noted double-peaked [O III] λ5007 and Hβ emission lines in spectra of the ELRs $\gtrsim$5$''$ north and south of the nuclear region. Our spectra from these positions (see Figure 1k) also show double-peaked Hα, [NII] and [S II] emission lines. A 'loop' of radio continuum emission extends to the north from the nuclear region (Wehrle & Morris 1987). These features imply the presence of a minor-axis wind which is blowing a shell of material northward (and perhaps southward) from the nucleus. Thus, there is very good evidence for a minor-axis outflow in NGC 5506.

4.1.14. IC 1368

Our Hα+[NII] image of IC 1368 is shown in Figure 1l. Note that the nuclear source is elongated in the direction of the minor axis and extends $\sim 5''$ (1.3 kpc) on each side of the nucleus. Such extended emission-line halos are commonly found in edge-on starburst galaxies with winds, so we have classified IC 1368 as a good candidate for a large-scale outflow.

4.1.15. IC 1417

Our Hα+[NII] image of his galaxy shows emission from the disk, but not from regions extending along the minor axis (Figure 1m).

4.1.16. NGC 7590

No extended emission is present in our Hα+[NII] image (Figure 1n). Much of the emission comes from clumpy H II regions in the disk.

4.2. Individual Objects: Additional Seyferts in the Extended Sample

For the following objects, there were no published data that is suitable for searching for a large-scale outflow: UGC 3255, ESO 362-G8, NGC 4117, IC 5169 and Mrk 915.

4.2.1. NGC 513

This galaxy has an elliptical R-band morphology (see Figure 2a). A bright ELR of luminosity $L_{\mathrm{H}\alpha+[\mathrm{NII}]} = 1 \times 10^{39}$ erg s^{-1} is noticeable 19.7″ (7.4 kpc) from the nucleus in P.A. 210°. The location of this ELR is not positioned exactly on the minor axis, but the gas is located ∼4 kpc (in projection) out of the disk. This suggests that it has been ejected from the disk. We have therefore classified NGC 513 as a good candidate for a large-scale outflow.

4.2.2. UGC 3255

We did not obtain images of UGC 3255. The position of the slit for our minor-axis spectra is shown in a greyscale plot of a B-band image (digitized survey plate) in Figure 2b. We did not find double-peaked line profiles or any evidence for ELRs extending out of the disk in our minor axis spectra.

4.2.3. ESO 362-G8

Conical ELRs can be seen in the Hα+[NII] image of this galaxy in Figure 2c. The northeast cone extents from the nucleus out to ∼14″ (4.3 kpc) along P.A. 65° (roughly perpendicular to the major axis) and has an Hα+[NII] luminosity of 1.8×10^{40} erg s^{-1}. Mulchaey, Wilson & Tsvetanov (1996) find the gas in the conical ELR to have high [O III]5007/Hα ratios, consistent with photoionization by the AGN. The presence of gas so far out of the disk suggests that a large-scale outflow is occurring in ESO 362-G8.

4.2.4. Mrk 10

The presence of extranuclear ELRs in Mrk 10 has been previously noted by Schulz (1982), who found line emission extending westward from the nucleus. We also find extranuclear line emission to be present from our long-slit data. The orientation of the slit (P.A. 40°) and a graph of the relative Hα flux for positions along the slit is shown in Figure 2d. Emission-line gas is present along the minor axis out to 20″ (11.3 kpc) to the northeast from the nuclear region, and out to 10″(5.6 kpc) to the southwest. Such emission could be produced by a galactic outflow blowing along the minor axis. However, due to the limited spatial coverage of our long-slit spectra, we classify this evidence as only suggestive. A more complete study of the extranuclear optical emission-line gas in Mrk 10 is clearly warranted.

4.2.5. NGC 4117

Our Hα+[NII] image (Figure 2e) of this galaxy shows emission from the inner disk but no extended emission along the minor axis. We did not find double-peaked line profiles or any evidence for ELRs extending out of the disk in our minor axis spectra.

4.2.6. NGC 5033

A patchy ring of H II regions shows up well in our Hα+[NII] image (Figure 2f). The field of view of our CCD is small (5′) compared to the large optical size of the galaxy (∼10′ × 5′), so our Hα+[NII] image is not very useful for looking for emission from extraplanar gas. The morphology of the Hα+[NII] emission within the stellar (R-band) envelope is not

elongated along the minor axis. We did not find double-peaked line profiles or any evidence for ELRs extending out of the disk in our minor axis spectra. This galaxy has been very well studied, but we did not find any evidence in the literature for a minor axis outflow.

4.2.7. IC 5169

The Hα+[NII] image (Figure 2g) shows ELRs extending along the minor axis, $\sim 6.5''$ (1.3 kpc) to the northwest and southeast of the nucleus, perpendicular to the bar. The total Hα+[NII] luminosity from the northwest ELRs is $\sim 10^{39}$ erg s^{-1}. The small, bright ELR south of the nucleus has a Hα+[NII] luminosity of $\sim 5 \times 10^{38}$ erg s^{-1} and the remaining southwest ELRs emit $\sim 10^{39}$ erg s^{-1}. Such emission could be produced by an outflow along the minor axis. However, the projected locations of the the ELRs are inside the stellar (R-band) envelope, so the ELRs may be located in the inner disk of IC 5169. For this reason, we classify this evidence as only suggestive of a minor-axis outflow.

4.2.8. Mrk 915 (MCG −2-57-23)

No emission is evident extending along the minor axis in our Hα+[NII] image (Figure 2h).

5. Discussion

5.1. Frequency of Occurrence of Minor-Axis Outflows in Seyfert Galaxies

The results from our observational data are listed symbolically in the last column of Table 4. For most of the objects we classified as good candidates for minor-axis outflows, either double-peaked emission lines are found from regions along the minor axis, or the morphology of the Hα+[NII] emission resembles that of a halo extending above and below the galaxy disk. In NGC 513 and ESO 362-G8, the nebulae have conical morphologies, similar to 'ionization cones' observed in some Seyfert galaxies (e.g. Pogge 1989, Wilson & Tsvetanov 1994). The line emission from the extranuclear gas in these objects could be produced by ionizing radiation from the AGN or by a shock from an outflowing jet. However, in both cases, the ELRs are found $\sim$4 kpc (in projection) out of the disk, which is, in general, further out than the typical maximum extent of ionization cones in Seyferts ($\sim$2 kpc, Wilson & Tsvetanov 1994). An obvious possible explanation for how the gas got so far out of the disk is that it was blown out by a minor-axis outflow. Thus we consider the six galaxies NGC 2992, IC 4329A, NGC 5506, IC 1368, NGC 513 and ESO 362-G8 to be good candidates for having large-scale minor axis outflows.

Our images and spectra of Ark 79, Mrk 10 and IC 5169 are suggestive of a minor axis wind, but are not entirely convincing in and of themselves. Therefore, we have not included them as 'good candidates' when calculating statistics for our samples. Further optical studies of the minor axis nebulae in these galaxies would be useful for determining if galactic outflows are present.

If we ignore the results in the literature and only consider results from the images and spectra we obtained, we find that for the 14 objects in our representative sample, four (29%) show good evidence for minor axis outflows. Including the objects from Table 2, six (27%) of the 22 objects in our extended sample show good evidence for minor axis outflows.

As mentioned in section 4.1, there is evidence in the literature for minor-axis outflows in two additional Seyferts in our complete sample (NGC 4388 and NGC 4945). All objects

which show good evidence for minor axis outflows (from our images and spectra or from the literature) are marked with an asterisk in Tables 1 and 2.

If we include the results from the literature, we find good evidence for minor axis outflows in four (29%) of the 14 objects in our representative sample, six (27%) of the 22 objects in our complete sample, and six (27%) of the 22 objects in our extended sample. The results are consistent: $\sim$25$-$30% of edge-on Seyferts show good evidence for large-scale galactic outflows.

These results underestimate the "true" fraction of Seyferts which have minor axis outflows. For many of the objects, data suitable for detecting emission from these outflows (e.g. Hα images, long-slit spectra of the minor-axis ELRs, deep radio-continuum images, deep X-ray images) are not available. In addition, our images are only sensitive to surface brightnesses $\gtrsim 10^{-16}$ erg s^{-1} cm^{-2} arcsec^{-2} and we have minor axis spectra to search for double-peaked emission lines for only nine of 22 objects observed. Detailed kinematic studies of extended emission-line regions in Seyferts are very useful for determining if an outflow is present, but such studies have been published for very few objects in our samples. Assuming our edge-on samples are unbiased subsamples of Seyfert galaxies, our results suggest that large-scale galactic outflows are likely to be present in $\gtrsim\frac{1}{4}$ of *all* Seyfert galaxies.

In Table 5, we list all Seyfert galaxies known (by us) to have good evidence for galactic outflows. Evidence comes in the form of optical emission-line nebulae and split emission lines along the minor axis, extended radio continuum emission along the minor axis, and extended X-ray halos along the minor axis. Most of the outflows which have been identified are in Seyferts with edge-on disks. Outflows in only a few of these galaxies (e.g. NGC 3079, Mrk 231 and NGC 4945) have been studied in detail.

5.2. Energy Source for the Large-Scale Outflows

The question of what powers large-scale outflows in Seyferts remains open even for the most well-studied cases. For example, in a very complete kinematic Fabry-Perot study of the two bi-symmetric wind-blown superbubbles in the nucleus of NGC 3079, Veilleux et al. (1994) found that either a starburst- or an AGN-driven wind was consistent. In the following subsections, we discuss two scenarios for powering the large-scale outflows in Seyferts: starburst-driven superwinds and outflows from the active nucleus.

5.2.1. Nuclear Starburst?

Superwinds in starburst galaxies have been fairly well studied (Heckman, Armus & Miley 1990; Lehnert & Heckman 1995), so it is natural to compare properties of large-scale outflows in Seyferts with those of superwinds in starburst galaxies. The superwind in the archetypical edge-on starburst galaxy M82 has an Hα+[NII] luminosity of $\sim 10^{40.3}$ erg s^{-1} and a kinetic luminosity of $10^{42.3}$ erg s^{-1} (Heckman, Armus & Miley 1990). We can estimate kinetic luminosities for the Seyfert outflows by scaling $L^{MINOR}_{H\alpha+[NII]}$ for our sample Seyferts (Table 4) by the ratio of the kinetic luminosity of M82 to the Hα+[NII] luminosity of its minor-axis ELRs. Using this method, we find kinetic luminosities $\sim 10^{40.5}-10^{42.2}$ erg s^{-1} (logarithmic mean $10^{41.4}$ erg s^{-1}) for the Seyfert outflows, assuming all of the line emission is produced by the outflow. The implied kinetic luminosities of our Seyfert outflows are, in general, a factor $\sim$0.1 as large as those of superwinds from Heckman, Armus & Miley (1990; several $\times$ 10^{42} erg s^{-1}). However, the mean far-IR luminosity of our sample ($<\log L_{FIR}>=$ 43.4 log[erg s^{-1}]) is smaller than that of Heckman, Armus & Miley's sample ($<\log L_{FIR}>=$ 44.9 log[erg s^{-1}]) by about the same factor, so if the Seyfert outflows are powered by nuclear starbursts, smaller kinetic luminosities are to be expected.

High rates of massive star formation have been inferred for the nuclear regions of several Seyfert galaxies. For example, in NGC 1068, approximately half of the IR luminosity comes from the AGN and the other half comes from the starburst (Balick & Heckman 1985). The energy input from a possible starburst is directly proportional to the starburst component of L_{FIR} (cf. Heckman, Lehnert & Armus 1993). However, for most Seyferts, separating the starburst and AGN components of L_{FIR} is not straightforward (cf. Telesco 1988; however, see also Rodriguez-Espinosa, Rudy & Jones 1987, who claim that star formation produces the bulk of the far-IR emission in Seyferts). Measuring massive-star formation rates from stellar absorption lines is in general, quite difficult to do in Seyferts (cf. Diaz 1992). Thus, it is not known how common circumnuclear starbursts are in Seyferts. Baum et al. (1993) could not distinguish between starburst- or AGN-driven winds using their radio data. However, they found that the luminosity of the extranuclear radio emission is comparable to that in starburst galaxies and follows the same radio-IR relation as that of starburst galaxies, suggesting that the large-scale radio emission may be of starburst origin. In order to verify that these galactic outflows are starburst-driven superwinds, one must find evidence for massive stars in the Seyfert nuclei and determine if the putative starburst is powerful enough to drive a galactic wind.

5.2.2. Active Nucleus?

The AGN can certainly provide enough energy to drive a galactic outflow. However, linear nuclear radio sources (suggestive of a collimated nuclear outflow) in Seyferts are not, in general, oriented along the same position angle as the large-scale diffuse radio emission (Baum et al. 1993). Therefore, it is unlikely that the large-scale minor-axis radio emission is from lobes at the end of collimated radio jets, as in powerful radio galaxies (unless the jet outflow axis precesses). On the other hand, if nuclear outflows from the AGN are

weak, they may lose energy to the interstellar medium in the nuclear region and become poorly-collimated. If the gas continues to flow outward, it may be be diverted toward the minor axis (where the pressure gradient is lowest) and continue on as a wide-angled outflow.

Many different models have been presented for nuclear outflows from AGNs. Theoretical models have been proposed for hydro-magnetic jets which originate from the accretion disk surrounding the black hole, or even from the black hole itself (cf. Blandford 1993). Another model (Krolik & Begelman 1986; Balsara & Krolik 1993) proposes that radiation-driven winds originate at the inner edge of the proposed molecular torus. Thus, estimating the amount of kinetic energy being channelled from the AGN into the outflow is highly model-dependent.

6. Summary and Conclusions

Large-scale galactic outflows are quite common in Seyfert galaxies. Our results show that they are present in $\gtrsim\frac{1}{4}$ of all Seyfert galaxies.

Current observational studies of these outflows do not offer enough information to conclude what drives the outflows. They may be powered by circumnuclear starbursts, AGN, or perhaps by both, in combination. In order to constrain the different models for the outflows, more observational work is needed to measure physical properties of these winds (e.g., outflow velocities, morphologies and luminosities of radio and X-ray halos, velocity and ionization structures of the outflowing gas near the nuclear region).

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Table 1. **Complete Statistical Sample of Edge-on Seyfert galaxies**

	Galaxy Name	Other Name	Galaxy[a] Type	R.A.[b] (J2000.0)	Dec[b]	log R_{25}[b]	cz[b] (km s^{-1})	Seyfert[c] Type	Refs	Data?
	IC 1657		(R′)SB(s)bc	01 14 07.3	−32 39 02	0.63	3552	2	1	
	UM 319	MCG 0-4-112	SB?	01 23 20.9	−01 58 36	0.43	4730	2	1,2,3	
	Mrk 993	UGC 987	Sa	01 25 31.5	+32 08 10	0.52	4658	2	1,3	†
	Mrk 577		S0/a	01 49 30.1	+12 30 32	0.41	5179	2	3	
	Ark 79	UGC 1757	S?	02 17 23.1	+38 24 50	0.53	5157	2	2,3	†
	NGC 931	Mrk 1040	Sbc	02 28 15.0	+31 18 46	0.67	4993	1	1,2,3	†
	NGC 1320	Mrk 607	Sa: sp	03 24 49.0	−03 02 31	0.47	2700	2	2,3	†
	NGC 1386		SB(s)0+	03 36 46.4	−35 59 58	0.42	864	2	1,2,3	†
*	NGC 2992		Sa pec	09 45 42.1	−14 19 39	0.51	2314	2	1,3	†
	MCG −2-27-9		SB(rs)0+ pec?	10 35 27.4	−14 07 49	0.60	4650	2	3	†
	NGC 4235	IC 3098	SA(s)a	12 17 08.9	+07 11 31	0.65	2410	1	1,2,3	†
*	NGC 4388		SA(s)b: sp	12 25 47.0	+12 39 42	0.64	2517	2	1	
	NGC 4602		SAB(rs)bc	12 40 37.1	−05 07 58	0.46	2548	1.9	3	†
*	NGC 4945		SB(s)cd: sp	13 05 26.2	−49 28 15	0.72	560	2	3	
*	IC 4329A		SA0+: sp	13 49 19.4	−30 18 35	0.56	4793	1	1,2,3	†
*	NGC 5506		Sa pec sp	14 13 14.9	−03 12 27	0.52	1815	2	1,2,3	†
	ESO 103-G35		SA0	18 38 20.3	−65 25 42	0.44	3983	2	1,3	
	NGC 6810		Sa	19 43 34.2	−58 39 21	0.55	1958	2	3	
*	IC 1368		Sa? sp	21 14 12.1	+02 10 38	0.44	3912	2	3	†
	IC 1417		Sb? sp	22 00 21.6	−13 08 48	0.58	4309	2	1,4	†
	NGC 7410		SB(s)a	22 55 00.7	−39 39 41	0.51	1751	2	2,3	
	NGC 7590		S(r?)bc	23 18 55.0	−42 14 17	0.42	1596	2	2,3	†

*Evidence exists for a minor-axis outflow (see section 4)

[a]Host galaxy morphology, taken from the NASA Extragalactic Database (NED)

[b]R.A., declination and Axial ratios (R_{25}) were taken from RC3. Recessional velocities (cz) were taken from (in preferential order): 21 cm values listed in RC3, optical values listed in RC3, Huchra 1993, Veron-Cetty & Veron 1991, and Hewitt & Burbidge 1991.

[c]Seyfert type. References: (1) Huchra 1993, (2) Veron-Cetty & Veron 1991, (3) Hewitt & Burbidge 1991, and (4) Maia et al. 1987

†Galaxy is in our representative sample – new optical data are presented for it in the present paper.

Table 2. **Additional Edge-on Seyferts in Extended Sample**

	Galaxy Name	Other Name	Galaxy[a] Type	R.A.[b] (J2000.0)	Dec[b] (J2000.0)	log R_{25}[b]	cz[b] (km s^{-1})	Seyfert[c] Type	Refs
*	NGC 513	Ark 41	S?	01 24 27.0	+33 47 57	0.31	5949	2	1,2,3
	UGC 3255		SBb?	05 09 48.0	+07 29 00	0.63	5689	2	1,2,3
*	ESO 362-G8		S0?	05 11 09.1	−34 23 36	0.34	4785	2	2,3
	Mrk 10		SBbc	07 47 29.1	+60 55 59	0.38	8753	1	1,2,3
	NGC 4117		S0:	12 07 46.2	+43 07 34	0.31	871	2	1,2
	NGC 5033		SA(s)c	13 13 28.0	+36 35 38	0.33	878	1	1,2
	IC 5169		(R_1)SAB(r)0+	22 10 09.7	−36 05 20	0.37	3016	2	1,4
	Mrk 915	MCG −2-57-23	S?	22 36 46.3	−12 32 40	0.45	7248	1	1,2

Edge-on Seyferts which we observed which did not satisfy the selection criteria for the complete sample (see section 2)

*Evidence exists for a minor-axis outflow (see section 4).

[a]Host galaxy morphology, taken from the NASA Extragalactic Database (NED)

[b]R.A. and declination and Axial ratios (R_{25}) were taken from RC3. Recessional velocities (cz) are optical (or 21 cm, when available) velocities listed in RC3.

[c]References for Seyfert types: (1) Huchra 1993, (2) Veron-Cetty & Veron 1991, (3) Hewitt & Burbidge 1991, and (4) Maia et al. 1987

Table 3. **Observing Log**

Date	Type	Instruments	Pixel Size	Wavelength Coverage
Jan 92	Long-slit Spectroscopy	GoldCam Spectrometer TI 800 × 800 CCD	0.78″ × 1.24Å	6200 − 7200 Å
Jun 92	Long-slit Spectroscopy	GoldCam Spectrometer Ford 3k × 1k CCD	0.78″ × 1.24Å	4800 − 7100 Å
Aug 92	Direct Imaging	Tek 1k × 1k CCD	0.3″	R,Hα
Feb 93	Direct Imaging	Tek 1k × 1k CCD	0.3″	R,Hα

All observations were performed at the 2.1 m telescope at KPNO.

Table 4. **Data for Galaxies in Extended Sample**

Galaxy Name	Images[1]	Source of Data[2]	Long Slit Spectra axis (P.A.)	Source of Data[2]	Fig no	$L_{H\alpha}^{TOTAL,3}$	$L_{H\alpha}^{MINOR,3}$	L_{FIR} [4]	Evidence[5]
Mrk 993	R,Hα+[NII]	1	maj (32°), min (122°)	2	1a	40.87	...	43.08	
Ark 79	R,Hα+[NII]	1	maj (87°), min (177°)	2	1b	40.95	...	...	S?
NGC 931	R	1	maj (73°), min (163°)	2	1c	...	...	43.87	
NGC 1320	R,Hα+[NII]	1	...	...	1d	40.62	...	43.21	
NGC 1386	6939Å, Hα+[NII]	3	...	...	1e	40.31	...	43.15	
NGC 2992	6680Å, Hα+[NII]	3	...	...	1f	41.11	38.5	43.66	I
MCG −2-27-9	R,Hα+[NII]	4	...	...	1g	40.94	...	43.21	
NGC 4235	R,Hα+[NII]	5	maj (48°), min (138°)	2	1h	40.38	...	42.36	
NGC 4602	5265Å, Hα+[NII]	3	...	...	1i	41.32	...	43.64	
IC 4329A	R,Hα+[NII]	4	...	...	1j	41.46	39.4	43.63	I
NGC 5506	5265Å, Hα+[NII]	3	maj (91°), min(1°)	2	1k	40.74	39.7	43.43	I,S
IC 1368	R,Hα+[NII]	1	maj (45°)	6	1l	40.56	39.5	43.82	I
IC 1417	R,Hα+[NII]	1	...	...	1m	40.78	...	43.14	
NGC 7590	5159Å, Hα+[NII]	3	...	...	1n	41.29	...	43.40	
NGC 513	R, Hα+[NII]	1	...	...	2a	41.42	39.0	43.93	I
UGC 3255	...	...	maj (17°), min (107°)	2	2b	...	...	43.68	
ESO 362-G8	R, Hα+[NII]	4	...	...	2c	41.07	40.2	43.18	I
Mrk 10	...	...	maj (130°), min (40°)	2	2d	...	...	43.92	S?
NGC 4117	6520Å, Hα+[NII]	4	maj (18°), min (108°)	2	2e	39.38	...	...	
NGC 5033	R, Hα+[NII][6]	5	maj (170°), min (80°)	2	2f	40.68[6]	...	43.22	
IC 5169	R, Hα+[NII]	4	...	...	2g	40.57	...	43.58	I?
Mrk 915	R, Hα+[NII]	1	...	...	2h	41.56	...	43.49	

The first 14 objects are those from our complete sample (i.e., this is our representative sample). All of the objects listed make up our extended sample.

[1]Images listed by Angstrom are narrow-band (FWHM ∼50−100Å) continuum images centered at that wavelength.

[2]Sources of Data: (1) images from the Aug 92 run, (2) spectra from the Jan 92 run, (3) images from Tsvetanov, Fosbury & Tadhunter (1995), (4) images from Mulchaey, Wilson & Tsvetanov (1996), (5) images from the Feb 93 run, and (6) spectra from the Jun 92 run.

[3]Total luminosity Hα+[NII] luminosity ($L_{H\alpha}^{TOTAL}$) and Hα+[NII] luminosity of minor axis emission-line regions ($L_{H\alpha}^{MINOR}$; see section 4 for details). Units are log(erg s^{-1}). $L_{H\alpha}^{TOTAL}$ is accurate to ∼20% (∼30% for NGC 4235 and IC 5033) and $L_{H\alpha}^{MINOR}$ is accurate to ∼50%.

[4]Far infrared luminosities in units of log(erg s^{-1}), calculated using the method described in Fullmer & Lonsdale (1989). IRAS fluxes are from Moshir et al. (1990) (taken from the NASA Extragalactic Database [NED]), except for UGC 3255, ESO 362-G8, NGC 2992 and NGC 7590. IRAS fluxes for these galaxies were taken from the IRAS Point Source Catalog (1988).

[5]Evidence for minor axis wind from images (I) or long-slit spectral data (S). Question mark indicates only suggestive evidence.

[6]CCD field of view is smaller than the optical size of the galaxy. The luminosity listed is for the field of view covered by the CCD.

Table 5. **Minor-Axis Outflows in Seyferts**

Galaxy Name	Seyfert Type	cz[1] (km s^{-1})	log R_{25}[1]	Evidence for Minor-axis Outflows References[2]	Notes[3]
NGC 513	2	5949	0.31	OI (1)	bright ELR approx along min axis possibly ion cone
ESO 362-G8	2	4830	0.34	OI (1)	v bright large-scale conical ELRs on min axis possibly ionized by AGN
NGC 2992	2	2314	0.51	OI (1),RI (2)	many bright large-scale ELRs radio bubble, v good evidence
NGC 3079	2?[4]	1125	0.74	OI,OS,RI,XI (3,4,5)	definite wind, well studied could be starburst- or AGN-driven
NGC 4388	2	2517	0.64	OI,OS,RI (6,7,8)	radial outflow of optically emitting gas radio finger perp to disk, good evidence
Mrk 231	1	12300	0.13	OS (9), RI (10)	definite wind could be starburst- or AGN-driven
NGC 4945	2	560	0.72	OI,OS (3,4)	definite wind, well studied could be starburst- or AGN-driven
IC 4329A	1	4800	0.56	OI (1)	bi-symmetric EL halo on min axis
NGC 5506	2	1830	0.52	OI,OS,RI (1,11,12)	double-peaked ELs from min axis ELRs radio bubble, v good evidence
NGC 5548	1	5149	0.05	OI,OS (13), RI (10)	definite min axis outflow may be from AGN
NGC 5728	2	2790	0.24	OI,OS (14)	conical ELRs and outflow along min axis may be from AGN
IC 1368	2	3912	0.44	OI (1)	bi-symmetric EL halo along min axis

[1]Recessional velocities (cz) and axial ratios (R_{25}) from RC3. If available, 21 cm velocities are quoted.

[2]References for evidence for minor-axis outflows (OI = optical images, OS = optical spectra, RI = radio continuum images, XI = X-ray images): (1) this paper, (2) Wehrle & Morris 1988, (3) Heckman, Armus & Miley 1990, (4) Heckman, Lehnert & Armus 1993, (5) Veilleux et al. 1994, (6) Corbin et al. 1988, (7) Hummel et al. 1983, (8) Stone et al. 1988, (9) Hamilton & Keel 1987, (10) Baum et al. 1993, (11) Wilson, Baldwin & Ulvestad 1985, (12) Wehrle & Morris 1987, (13) Wilson et al. 1989, (14) Schommer et al. 1988.

[3]Abbreviations for notes: EL = emission-line, ELR = emission-line region, ion = ionization, min = minor, poss = possible, v = very, perp = perpendicular

[4]NGC 3079 has a LINER-type optical nuclear spectrum, but it may house a weak Seyfert nucleus.

REFERENCES

Amram, P., Marcelin, M., Bonnarel, F., Boulesteix, J., Afanasiev, V. L., & Dodonov, S. N. 1992, A&A, 263, 69

Antonucci, R. R. J. 1993, ARA&A, 31, 473

Balick, B., & Heckman, T. M. 1985, AJ, 90, 197

Balsara, D. S., & Krolik, J. J. 1993, ApJ, 402, 109

Baum, S. A., O'Dea, C. P., Dallacassa, D., de Bruyn, A. G., & Pedlar, A. 1993, ApJ, 419, 553

Blandford, R. D. 1993, in Astrophysical Jets, ed. D. Burgarella, M. Livio & C. P. O'Dea (Cambridge: Cambridge University Press), p. 15

Bregman, J. N. 1994, in The Soft X-ray Cosmos: Proc. of the ROSAT Science Symposium, ed. E. Schlegel & R. Petre (New York: AIP), p. 164

Buta, R., & de Vaucouleurs, G. 1983, ApJS, 51, 149

Corbin, M. R., Baldwin, J. A., & Wilson, A. S. 1988, ApJ, 334, 584

Dettmar, R.-J. 1992, Fund. Cosmic Phys., 15, 143

Diaz, A. I. 1992, in Relationships Between Active Galactic Nuclei and Starburst Galaxies, ed. A. V. Filippenko (San Francisco: ASP), p. 181

de Vaucouleurs, G., de Vaucouleurs, A., Corwin, H. G., Buta, R. J., Paturel, G., & Fouque, P. 1991, Third Reference Catalog of Bright Galaxies (RC3; New York: Springer-Verlag)

Fullmer, L., & Lonsdale, C. 1989, Cataloged Galaxies and Quasars in the IRAS Survey (JPL Pub. D-1932, Version 2, Appendix B)

Hamilton, D., & Keel, W. C. 1987, ApJ, 321, 211

Harnett, J., Haynes, R., Klein, U., & Wielebinski, R. 1989, A&A, 216, 39

Heckman, T. M., Armus, L., & Miley, G. K. 1990, ApJS, 74, 833

Heckman, T. M., Lehnert, M. D., & Armus, L. 1993, in The Environment and Evolution of Galaxies, ed. J. M. Shull & H. A. Thronson (Dordrecht: Kluwer), p. 455

Hewitt, A. & Burbidge, G. 1991, ApJS, 75, 297

Huchra, J. 1993, private communication (updated electronic version of "Catalogue of Seyfert Galaxies and Other Bright AGN")

Hummel, E., Beck, R., & Dettmar, R.-J. 1991, A&AS, 87, 309

Hummel, E., van Gorkom, J., & Kotanyi, C. 1983, ApJ, 267, L5

Keel, W. C., & Wehrle, A. E. 1993, AJ, 106, 236

Krolik, J. H., & Begelman, M. C. 1986, ApJ, 308, L55

Lehnert, M. D., & Heckman, T. M. 1995, ApJS, 97, 89

Maia, M. A. G., da Costa, L. N., Willmer, C., Pellegrini, P. S. & Rite, C. 1987, AJ, 93, 546

Moshir, et al. 1990, IRAS Faint Source Catalog, version 2

Mulchaey, J. S., Wilson, A. S., & Tsvetanov, Z. 1996, ApJS, in press (Feb 10 issue)

Pogge, R. W. 1988, ApJ, 332, 702

Pogge, R. W. 1989, ApJ, 345, 730

Rand, R. J. 1995, in Gas Disks in Galaxies, ed. J. M. van der Hulst (The Hague: Kluwer), in press

Rodriguez-Espinosa, J. M., Rudy, R. J., & Jones, B. 1987, ApJ, 312, 555

Schommer, R. A., Caldwel, N., Wilson, A. S., Baldwin, J. A., Phillips, M. M., Williams, T. B., & Turtle, A. J. 1988, ApJ, 324, 154

Schulz, H. 1982, A&A, 115, 209

Scoville, N. Z. 1992, in Relationships Between Active Galactic Nuclei and Starburst Galaxies, ed. A. V. Filippenko (San Francisco: ASP), p. 159

Seaquist, E. & Odegard, N. 1991, ApJ, 369, 320

Stone, J. L., Jr., Wilson, A. S., & Ward, M. J. 1988, ApJ, 330, 105

Telesco, C. M. 1988, ARA&A, 26, 343

Terlevich, R. 1992, in Relationships Between Active Galactic Nuclei and Starburst Galaxies, ed. A. Filippenko (San Francisco: ASP), p. 133

Tsvetanov, Z., Dopita, M., & Allen, M. 1995, B.A.A.S., Vol. 26, No. 5, p. 871

Tsvetanov, Z. I., Fosbury, R. A. E., & Tadhunter, C. N. 1995, ApJS, submitted

Ulvestad, J. S., & Wilson, A. S. 1984, ApJ, 285, 439

Ulvestad, J. S., & Wilson, A. S. 1989, ApJ, 343, 659

Unger, S. W., Lawrence, A., Wilson, A. S., Elvis, M., & Wright, A. E. 1987, MNRAS, 228, 521

Veilleux, S., Cecil, G., Bland-Hawthorn, J., Tully, R. B., Filippenko, A. V., & Sargent, W. L. W. 1994, ApJ, 433, 48

Veron-Cetty, M. P., & Veron, P. 1991, electronic version of "A Catalog of Quasars and Active Nuclei," 5th ed. (ESO Sci. Rep. No. 10)

Weaver, K. A., Wilson, A. S., & Baldwin, J. A. 1991, ApJ, 366, 50

Wehrle, A. E., & Morris, M. 1987, ApJ, 313, L43

Wehrle, A. E., & Morris, M. 1988, AJ, 95, 1689

Wilson, A. S. 1993, in Astrophysical Jets, ed. D. Burgarella, M. Livio & C. P. O'Dea (Cambridge: Cambridge University Press), p. 121

Wilson, A. S., Baldwin, J. A., & Ulvestad, J. S. 1985, ApJ, 291, 627

Wilson, A. S., & Tsvetanov, Z. I. 1994, AJ, 107, 1227

Wilson, A. S., Wu, X., Heckman, T. M., Baldwin, J. A., & Balick, B. 1989, ApJ, 339, 729

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Figure 1 – Images and minor-axis spectra for the 14 objects observed in our complete sample. Levels for all of the contour plots of the images differ by a multiplicative factor of 2. The highest level for the contour plots of the R-band and continuum images is 50% of the maximum surface brightness. Slit positions for the minor-axis spectra are overlayed on the contour plots. **(a) Mrk 993.** Contour plots of the R-band emission (left) and the Hα+[NII] emission (right). The lowest level displayed in the Hα+[NII] contour plot is 0.5 $\times$ 10^{-16} erg s^{-1} cm^{-2} arcsec^{-2}. **(b) Ark 79.** Contour plots of the R-band emission (left) and the Hα+[NII] emission (right). The lowest level displayed in the Hα+[NII] contour plot is 0.5 $\times$ 10^{-16} erg s^{-1} cm^{-2} arcsec^{-2}. Also shown are spectra (effective aperture 2.0$''$ $\times$ 2.34$''$) from the nucleus and from regions 3.1$''$ (1 kpc) north and south of the nucleus, along the minor axis. **(c) NGC 931.** Contour plot of the R-band emission (left). Emission was detected along the minor axis, but it is from the companion galaxy located $\sim$20$''$ to the north. **(d) NGC 1320.** Its companion galaxy NGC 1321 lies $\sim$1.7$'$ to the north of NGC 1320. Contour plots of the R-band emission (left) and the Hα+[NII] emission (right). The lowest level displayed in the Hα+[NII] contour plot is 1.0 $\times$ 10^{-16} erg s^{-1} cm^{-2} arcsec^{-2}. **(e) NGC 1386.** Contour plots of the red continuum emission (left) and the Hα+[NII] emission (right). The lowest level displayed in the Hα+[NII] contour plot is 2.0 $\times$ 10^{-16} erg s^{-1} cm^{-2} arcsec^{-2}. **(f) NGC 2992.** Contour plots of the red continuum emission (left) and the Hα+[NII] emission (right). The lowest level displayed in the Hα+[NII] contour plot is 1.0 $\times$ 10^{-16} erg s^{-1} cm^{-2} arcsec^{-2}. **(g) MCG −2-27-9.** Contour plots of the R-band emission (left) and the Hα+[NII] emission (right). The lowest level displayed in the Hα+[NII] contour plot is 2.0 $\times$ 10^{-16} erg s^{-1} cm^{-2} arcsec^{-2}. **(h) NGC 4235.** Contour plots of the R-band emission (left) the Hα+[NII] emission (right). The lowest level displayed in the Hα+[NII] contour plot is 1.0 $\times$ 10^{-16} erg s^{-1} cm^{-2} arcsec^{-2}. **(i) NGC 4602.** Contour plots of the green continuum emission (left) and the Hα+[NII] emission (right). The lowest level displayed in the Hα+[NII] contour plot is 2.0 $\times$ 10^{-16}

erg s^{-1} cm^{-2} $arcsec^{-2}$. **(j) IC 4329A.** Contour plots of the R-band emission (left) and the Hα+[NII] emission (right). The lowest level displayed in the Hα+[NII] contour plot is 2.0×10^{-16} erg s^{-1} cm^{-2} $arcsec^{-2}$. **(k) NGC 5506.** Contour plots of the green continuum emission (left) and the Hα+[NII] emission (right). The lowest level displayed in the Hα+[NII] contour plot is 1.0×10^{-15} erg s^{-1} cm^{-2} $arcsec^{-2}$. Also shown are spectra (effective aperture $2.0'' \times 2.34''$) from the nucleus and from regions $6.2''$ (0.7 kpc) north and south of the nucleus, along the minor axis. **(l) IC 1368.** Contour plots of the R-band emission (left) and the Hα+[NII] emission (right). The lowest level displayed in the Hα+[NII] contour plot is 1.0×10^{-16} erg s^{-1} cm^{-2} $arcsec^{-2}$. **(m) IC 1417.** Contour plots of the R-band emission (left) and the Hα+[NII] emission (right). The lowest level displayed in the Hα+[NII] contour plot is 0.5×10^{-16} erg s^{-1} cm^{-2} $arcsec^{-2}$. **(n) NGC 7590.** Contour plots of the green continuum emission (left) and the Hα+[NII] emission (right). The lowest level displayed in the Hα+[NII] contour plot is 4.0×10^{-16} erg s^{-1} cm^{-2} $arcsec^{-2}$.

Figure 2 – Images and minor-axis spectra for eight objects observed which were not in our complete sample. Levels for all of the contour plots of the images differ by a multiplicative factor of 2. The highest level for the contour plots of the R-band and continuum images is 50% of the maximum surface brightness. Slit positions for the minor-axis spectra are overlayed on the contour plots. **(a) NGC 513.** Contour plots of the R-band emission (left) and the Hα+[NII] emission (right). The lowest level displayed in the Hα+[NII] contour plot is 0.5×10^{-16} erg s^{-1} cm^{-2} arcsec^{-2}. **(b) UGC 3255.** Linearly-scaled greyscale plot of the B-band emission from a digitized sky survey plate obtained at STScI (left). **(c) ESO 362-G8.** Contour plots of the R-band emission (left) and the Hα+[NII] emission (right). The lowest level displayed in the Hα+[NII] contour plot is 1.0×10^{-16} erg s^{-1} cm^{-2} arcsec^{-2}. **(d) Mrk 10.** Linearly-scaled greyscale plot of the B-band emission from a digitized sky survey plate obtained at STScI (left). We also show the relative intensity of the Hα line emission along the minor-axis slit. **(e) NGC 4117.** Contour plots of the red continuum emission (left) and the Hα+[NII] emission (right). The lowest level displayed in the Hα+[NII] contour plot is 1.0×10^{-16} erg s^{-1} cm^{-2} arcsec^{-2}. **(f) NGC 5033.** Contour plots of the R-band emission (left) and the Hα+[NII] emission (right). The lowest level displayed in the Hα+[NII] contour plot is 1.0×10^{-16} erg s^{-1} cm^{-2} arcsec^{-2}. Note that the field of view of the CCD was smaller than the extent of the emission from the galaxy. **(g) IC 5169.** Contour plots of the R-band emission (left) and the Hα+[NII] emission (right). The lowest level displayed in the Hα+[NII] contour plot is 2.0×10^{-16} erg s^{-1} cm^{-2} arcsec^{-2}. **(h) Mrk 915.** Contour plots of the R-band emission (left) and the Hα+[NII] emission (right). The lowest level displayed in the Hα+[NII] contour plot is 1.0 $\times 10^{-16}$ erg s^{-1} cm^{-2} arcsec^{-2}.

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